Manuscript TC-2020-219:

Atmospheric extremes triggered the biggest calving event in more than 50 years at the Amery Ice shelf in September 2019.

By D. Francis et al.

Reply to reviewers' comments

The authors would like to thank the reviewers for their valuable comments which will help to improve the quality of the manuscript. Kindly find below in blue our response point-by-point to the reviewers' comments and suggestions.

Reviewer #1:

This submission deals with the weather and synoptic conditions occurring at the time of the dramatic breakoff of iceberg D28 from the Amery Ice Shelf in September last year. The study explores, and implicates, the conditions of the forcings from twin polar explosive cyclones and their associated consequences. The analysis is comprehensive and considers the effects of the dynamics (very anomalous strong winds, stress, active wave field, and moisture transports) and moist thermodynamics (transport of sensible and latent heat) and other relevant issues. The text and the logical structure of the paper make it easy to read, and it presents some important insights. I requesting that the authors revise the manuscript in line with the comments I make below.

Thank you for your positive feedback on the merit of our manuscript. Our response to the specific comments is below.

1) As part of the Introduction (and context) and perhaps later discussion it would be valuable to reference the recent analysis (and perspectives) of Teng Li, Yan Liu and Xiao Cheng, 2020: Recent and imminent calving events do little to impair Amery ice shelf's stability. Acta Oceanologica Sinica, 39, 168-170, doi: 10.1007/s13131-020-1600-6.

Agreed.

2) Similar comment with respect to the earlier, but still very relevant, investigation of Simone Darji, Sandip R. Oza, R. D. Shah, B. P. Rathore and I. M. Bahuguna, 2018: Rift assessment and potential calving zone of Amery Ice Shelf, East Antarctica. Current Science, 115, 1799-1804, doi: 10.18520/cs/v115/i9/1799-1804.

Agreed.

3) LINE 97 – 101 – In this context very beneficial to also reference the studies of Rudeva et al., 2015: Variability and trends of global atmospheric frontal activity and links with large-scale modes of variability. J. Clim, 28, 3311-3330, and Pezza and co-authors, 2007: Southern Hemisphere cyclones and anticyclones: Recent trends and links with decadal variability in the Pacific Ocean. Int. J. Climat., 27, 1403-1419.

Agreed.

4) LINES 101-103 - Questions have been raised in the literature in connection with the interpretation of ‘cyclone’ statistics and their trends. There are many automated cyclone identification schemes and the different choices made in these can give rise to different results (refer here to, e.g., Neu, U. et al., 2013: IMILAST: A community effort to intercompare extratropical cyclone detection and tracking algorithms. Bull. Amer. Meteor. Soc., 94, 529-547). Regarding the potential influence of this on the analysis of future trends very helpful here to cite the investigation of U. Ulbrich, Gregor C. Leckebusch, Jens Grieger, et al., 2013: Are greenhouse gas signals of Northern Hemisphere winter extra-tropical cyclone activity dependent on the identification and tracking algorithm? Meteor. Zeitschrift, 22, 61-68 who find robustness across state-of the-art cyclone schemes for the NH.

Agreed.

5) LINE 106 – Note that Jim Kossin’s paper deals with tropical cyclones, rather than extratropical cyclones. In the context here (of ETCs), including this reference is perhaps misleading.

Agreed. We will replace this reference by a reference relevant to ETCs.

6) LINE 107-119 As part of this broad Introduction it would be helpful to refer to the analysis of Uotila, Vihma, et al., 2011: Relationships between Antarctic cyclones and surface conditions as derived from high resolution NWP data. J. Geophys. Res., 116, doi: 10.1029/2010JD015358 for quantification of the many interactions between Antarctic cyclones and surface parameters of relevance to the present study.

Agreed.

7) LINES 112-114 – As made clear here, these cyclones and ‘rivers’ transport poleward significant amounts of heat and moisture. Recent investigations have revealed the significant consequences in the polar regions of increased downward longwave radiation on sea ice melt and temperature. This important radiative aspect should be explicitly mentioned, and reference made to Lee, Gong, et al., 2017. ’Revisiting the cause of the 1989-2009 Arctic surface warming using the surface energy budget: Downward infrared radiation dominates the surface fluxes’, Geophys. Res. Lett. 44,10,654–10,661.

Agreed.

8) LINE 113 – Here (and in a number of other places in the text) the authors refer to Francis et al. (2019). However, in the References there are details of Francis et al. (2019a) and Francis et al. (2019b) (lines 594-599). Please sort this out.

Done.

9) LINES 115-119 - There is a significant amount of research and new insights now on this key topic. Consider updating the references with Vernon A. Squire, 2020: Ocean wave interactions with sea ice: A reappraisal. Annual Review of Fluid Mechanics, 52, 37-60, doi: 10.1146/annurev-fluid-010719-060301. Vernon A. Squire, 2018: A fresh look at how ocean waves and sea ice

interact. Philosophical Transactions of the Royal Society A - Mathematical Physical and Engineering Sciences, 376, 20170342, doi: 10.1098/rsta.2017.0342.

Agreed. Thanks for pointing us to these references.

10) LINES 192-202 – The authors speak here of the synoptic conditions exhibiting an amplified zonal wave number 3 (ZW3). I strongly suggest wording this more carefully. 'zonal wave number 3' can broadly speaking be thought of as three ridges (or troughs) spaced approximately equally around the SH. However, it is more rigorously taken to be the quantitative metric defined by Marilyn Raphael (2004, 2007) as the average normalised geopotential (or pressure) at the three points (49S, 50E), (49S, 166E), and (49S, 76W). A problem that arises from this fixed-locations definition is that the 3-wave structure shows considerable longitudinal variability. In fact, the 3-wave structure shown in Fig. 2a is shifted to the west of the above points by some 35 degrees, i.e., over a quarter of a wavelength. Recent research has been directed at defining a ZW3 which allows for these translations (make reference here to Irving and co-authors (2015) A novel approach to diagnosing Southern Hemisphere planetary wave activity and its influence on regional climate variability. J. Clim. 28, 9041-9057). To avoid misleading the reader on this important point please make some more targeted comments here (and where relevant elsewhere) in the paper.

Thanks very much for this insight. Agreed, indeed the reference you are suggesting is more relevant and will be used.

11) LINE 216-217 – To avoid any NH/SH confusion I suggest changing ' ... to the left of the low-pressure center' to ' ... to the west of the low-pressure center'. While 'left' is strictly correct for this limited region plot, it has the potential to obscure the physical relationship. Please make similar changes to 'left' at lines 219, 342, ...

Agreed. The necessary changes will be made.

12) LINE 225 – You have used 'standard deviations' up till now. Perhaps be consistent and replace this for 'sigma'. (Similar comment for line 242.)

Agreed.

13) LINE 277-296 – Figure 5 shows lots of very interesting structure. Two panels show IVT and TCWV, but it would be interesting to also show precipitation. While I don't absolutely require this, it would be valuable in indicating the magnitude of the lower atmosphere latent heat release and its potential role in driving these extreme systems.

Agreed. We have added precipitation to figure 5 and will be included in the revised version of the manuscript.

14) LINE 318-319 – Figure 6f presents much valuable information in a neat form.

Thanks.

15) LINE 623-624 – Please present full details. They are ... Hersbach, H., B. Bell, P. Berrisford, et al., 2020: The ERA5 global reanalysis. Quarterly Journal of the Royal Meteorological Society, 146, 1999–2049, doi: 10.1002/qj.3803.

Done.

16) LINE 766-768 – Wille, J. D., V. Favier, A. Dufour, I. V. Gorodetskaya, J. Turner, C. Agosta and F. Codron, 2019: West Antarctic surface melt triggered by atmospheric rivers. Nature Geoscience, 12, 911-916, doi: 10.1038/s41561-019-0460-1.

Done.